

## SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Kaori Fujimura, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan, Kiyotaka Otsuji, a citizen of Japan residing at Kamakura-shi, Kanagawa-ken, Japan, Yuichi Fujino, a citizen of Japan residing at Kiyose-shi, Tokyo-to, Japan, Sakuichi Ohtsuka, a citizen of Japan residing at Yokohama-shi, Kanagawa-ken, Japan, Koji Ogawa, a citizen of Japan residing at Yokohama-shi, Kanagawa-ken, Japan, Hitomi Sato, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan and Harumi Kawashima, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan have invented certain new and useful improvements in

TOMOGRAPHIC IMAGE READING METHOD, AUTOMATIC ALIGNMENT  
METHOD, APPARATUS AND COMPUTER READABLE MEDIUM

of which the following is a specification:-

2 179105586

TITLE OF THE INVENTION

TOMOGRAPHIC IMAGE READING METHOD,  
AUTOMATIC ALIGNMENT METHOD, APPARATUS AND COMPUTER  
READABLE MEDIUM

5

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to  
a slice image automatic alignment method and  
10 apparatus used for comparing a tomographic image of  
an object such as a computerized tomography (CT)  
image with another tomographic image of the same  
object which are taken at different times. The  
tomographic image is generated by CT, MRI(magnetic  
15 resonance imaging) or the like.

2. Description of the Related Art

In a medical field, comparison between a  
present image and a previous image provides a clue  
for determining whether a shade in an image is a  
20 tumor or not and whether it is malignant or not. As  
one method for the comparison of images, when a  
doctor finds a suspicious shade in a diagnostic  
image, the doctor may search for comparison images  
showing a position which corresponds to that of the  
25 diagnostic image so as to compare the images. The  
technique for supporting the doctor to compare  
images is disclosed in, for example, "METHOD FOR  
AUTOMATICALLY COMPARING SLICED IMAGES OF CHEST  
THREE-DIMENSIONAL TOMOGRAPHIC IMAGES", Japanese  
30 laid-open patent application No.10-53172 and  
"COMPARATIVE INTERPRETATION OF RADIOGRAM BY CT IMAGE  
FOR MASS EXAMINATION", Ukai et al., JAMIT  
Frontier '98, ppl40-145.

The above-mentioned technique in "METHOD  
35 FOR AUTOMATICALLY COMPARING SLICED IMAGES OF CHEST  
THREE-DIMENSIONAL TOMOGRAPHIC IMAGES" is a method  
for comparing each slice of the diagnostic images

with comparison image slices for finding a corresponding comparison image. Although the method can cope with changes of body condition and movement of the lower part of a lung for breathing, there is  
5 a problem that the process takes a long time since the slice needs to be compared with comparison image slices one by one. According to the above-mentioned conventional technique "COMPARATIVE INTERPRETATION OF RADIOGRAM BY CT IMAGE FOR MASS EXAMINATION",  
10 sections of a lung field are classified, then, features such as a lung field area, a heart area, and a descending aorta are extracted and automatic image comparison is performed on the basis of the location of the features. However, there is a  
15 problem that it takes a long time to extract the features.

Accordingly, when a doctor carries out diagnosis by comparing chest tomographic images, it takes time to see a comparison image which  
20 corresponds to the diagnostic image, or it is necessary to compare present images with previous images. In this case, since all images need to be compared, normal images as well as suspicious images need to be compared. Therefore, it takes time to  
25 perform often useless comparisons.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide a tomographic image reading method, an  
30 automatic alignment method, the apparatus and the computer readable medium in which slice images of the same body position can be obtained automatically at high speed from two sequences of chest tomographic images of the same person such that the  
35 slice images can be presented to a doctor in a short time.

The above object of the present invention

is achieved by a tomographic image reading method for extracting a comparison image corresponding to a diagnostic image and displaying the images, the diagnostic image being a slice image which is one of  
5 first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at a time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial  
10 direction and body axis being in the Z axial direction, the method comprising the steps of:

inputting the first tomographic images and the second tomographic images;

generating a first projection image from  
15 the first tomographic images and a second projection image from the second tomographic images;

measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same  
20 area using a template, the template being generated from the first projection image such that the template includes an area in which a specific object image exists;

correcting the slice position according to  
25 the shift amount between the first projection image and the second projection image; and

displaying the diagnostic image and the comparison image at a corrected slice position to a monitor.

30 According to the above-mentioned method for aligning positions of diagnostic images and comparison images so as to extract a comparison image corresponding to a diagnostic image, since the projection image is used, the shift can be detected  
35 quickly, and a diagnostic image and a comparison image in which slice position shift is corrected can be displayed on a monitor in a short time.

The above object of the present invention is also achieved by an image alignment method for extracting a comparison image corresponding to a diagnostic image and displaying the images, the  
5 diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at a time different from the time when the first tomographic images are taken,  
10 body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the method comprising the steps of:

inputting the first tomographic images and the second tomographic images;

15 aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

20 generating a first projection image from the first tomographic images and a second projection image from the second tomographic images;

measuring shift amount between the first projection image and the second projection image by  
25 searching the second projection image for the same area using a template by performing pattern matching while shifting the template by an interval, the template being generated from the first projection image such that the template includes an area in  
30 which a specific object image exists;

correcting the slice position according to the shift amount between the first projection image and the second projection image; and

35 displaying the diagnostic image and the comparison image at a corrected slice position on a monitor.

The image alignment method may include an

adjusting step of adjusting positions of the diagnostic image and the comparison image which are displayed;

wherein a MIDI signal constructing method  
5 is used for the adjusting step, the MIDI signal constructing method comprising the steps of:

providing  $n$  different MIDI channels or control numbers or combinations of them for a signal  $x$  which has  $128 \times n$  stages in which  $n$  is a positive  
10 integer;

assuming the MIDI channels or the control numbers or the combinations as  $p=1, 2, \dots, n$ ;

dividing the signal  $x$  into 128 parts  $W(1)(1; 0 \leq l \leq 127)$  in ascending order and assigning  $p$   
15 which is equal to  $r+1$  ( $r; 0 \leq r < n$ ) to the signal  $x$  which is equal to  $1 \times n + r$ ;

constructing and sending a MIDI control change message in which a control value is 1 by using a MIDI channel or control number corresponding  
20 to  $p$ .

According to the above method, automatic position alignment can be performed at high speed and the result can be displayed. In addition, the displayed image can be adjusted precisely. That is,  
25 by using the MIDI signal constructing method for the terminal operation, the operation can be performed effectively.

The above object of the present invention is also achieved by a slice image automatic  
30 alignment method for extracting a comparison image corresponding to a diagnostic image, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic  
35 images which are taken at a time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial



sequence comprising pixel values obtained by adding pixel values of the tomographic images in the X or Y axial direction or in any other direction; and

generating the projection image by  
5 interpolating the two dimensional image sequence.

According to the method, the position of slice images can be aligned accurately.

In the above-mentioned method, the template may be an area of 25% to 50% from the top  
10 end of the first projection image in the Z axial direction. Accordingly, pattern matching can be performed effectively. Especially, when the object part is lung, the effect is remarkable.

The above object of the present invention  
15 is also achieved by a slice image automatic alignment method for extracting a comparison image corresponding to a diagnostic image, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a  
20 slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial  
25 direction, the method comprising the steps of:

inputting the first tomographic images and the second tomographic images;

aligning resolutions of the first tomographic images and the second tomographic images  
30 by scaling one or both of the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

finding a reference position in the Y axial direction for each of the first tomographic  
35 images and the second tomographic images and correcting shift in the Y axial direction on the basis of the reference position;

5                   measuring shift amount between the first  
projection image and the second projection image by  
searching the second projection image for the same  
area as a template by performing pattern matching  
while shifting the template by an interval, the  
0   template being generated from the first projection  
image such that the template includes an area in  
which a specific object image exists; and

The above object of the present invention is also achieved by a slice image automatic alignment method for extracting a comparison image corresponding to a diagnostic image, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the method comprising the steps of:

30 aligning resolutions of the first  
tomographic images and the second tomographic images  
by scaling one or both of the tomographic images  
when the resolutions of the first tomographic images  
and the second tomographic images are different;

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35         generating a first projection image in the
X axial direction from the first tomographic images
and generating a second projection image in the X

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axial direction from the second tomographic images;

finding a reference position in the Y  
axial direction from each of the first projection  
image and the second projection image and correcting  
5 shift in the Y axial direction on the basis of the  
reference position;

measuring shift amount between the first  
projection image and the second projection image by  
searching the second projection image for the same  
10 area using a template by performing pattern matching  
while shifting the template by an interval, the  
template being generated from the first projection  
image such that the template includes an area in  
which a specific object image exists; and

15 correcting the slice position according to  
the shift amount between the first projection image  
and the second projection image.

In the above-mentioned method, the step of  
generating projection images may include the step  
20 of:

generating a two dimensional image  
sequence comprising pixel values obtained by adding  
pixel values of the tomographic images in the X  
axial direction; and

25 generating the projection image by  
interpolating the two dimensional image sequence.

The step of finding the reference position  
and correcting shift may include the steps of:

extracting a bed area as the reference  
30 position from the first tomographic image and the  
second tomographic image or the first projection  
image and the second projection image;

correcting shift in the Y axial direction  
on the basis of the bed surface, the Y axial  
35 direction being perpendicular to the bed surface.

In addition, the step of finding the  
reference position and correcting shift may include

the steps of:

finding a body part which contacts the bed  
as the reference position from the first tomographic  
image and the second tomographic image or the first  
5 projection image and the second projection image;

correcting shift in the Y axial direction  
on the basis of the part, the Y axial direction  
being perpendicular to the part.

Further, the step of finding the reference  
10 position and correcting shift may include the steps  
of:

finding a backbone part as the reference  
position from the first tomographic image and the  
second tomographic image or the first projection  
15 image and the second projection image;

correcting shift in the Y axial direction  
on the basis of the backbone part, the Y axial  
direction being perpendicular to the backbone part.

According to the above mentioned methods,  
20 the shift can be detected quickly. By correcting  
the shift in the comparison images, automatic  
aligning of slice images can be performed quickly.  
In addition, since shift correcting is performed by  
using the bed position or a distinctive part of the  
25 body as a reference, search area can be decreased.  
Therefore, calculation amount can be decreased.

In the above mentioned invention, the step  
of generating projection images may include the step  
of generating the projection image in which weight  
30 is assigned to a specific observation object by  
setting a window level and a window width.

According to the method, better matching  
results for a specific part such as bone or lung  
tissue and speedy processing can be realized.

35 Further, the step of generating projection  
images may includes the step of generating the  
projection image in which only a part including a

distinctive part is projected.

According to the method, the area of the projection image or the search area can be narrowed. Therefore, better matching results for a specific  
5 part and speedy processing can be realized.

Further, the step of measuring the shift amount may include the steps of:

generating a plurality of templates;  
performing template matching on the second  
10 projection image by using a plurality of templates;  
and

measuring shift amount between the first projection image and the second projection image from a plurality of reference points.

15 According to the method, shift correction of the slice position becomes more accurate and the better matching result can be obtained. Especially, when comparing the lower part of lung, shift due to breathing can be corrected.

20 The above object of the present invention is also achieved by a tomographic image reading apparatus for extracting a comparison image corresponding to a diagnostic image and displaying the images, the diagnostic image being a slice image  
25 which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken, body section being a  
30 slice plane in the X-Y axial direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first tomographic images and the second tomographic  
35 images;

projection image generation means for generating a first projection image from the first

tomographic images and a second projection image from the second tomographic images;

template generation means for generating a template from the first projection image such that  
5 the template includes an area in which a specific object image exists;

matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection  
10 image for the same area as the template;

slice position correcting means for correcting the slice position according to the shift amount between the first projection image and the second projection image; and

15 displaying means for displaying the diagnostic image and the comparison image at a corrected slice position on a monitor.

According to the invention, since the projection image is used, the shift can be detected  
20 quickly and a diagnostic image and a comparison image in which slice position shift is corrected can be displayed on a monitor in a short time.

The above object of the present invention is also achieved by an image alignment apparatus for  
25 extracting a comparison image corresponding to a diagnostic image and displaying the images, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic  
30 images which are taken at a time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the apparatus comprising:

35 inputting means for inputting the first tomographic images and the second tomographic images;

resolution aligning means for aligning  
resolutions of the first tomographic images and the  
second tomographic images by scaling one or both of  
the tomographic images when the resolutions of the  
5 first tomographic images and the second tomographic  
images are different;

projection image generation means for  
generating a first projection image from the first  
tomographic images and a second projection image  
10 from the second tomographic images;

template generation means for generating a  
template from the first projection image such that  
the template includes an area in which a specific  
object image exists;

15 matching means for measuring shift amount  
between the first projection image and the second  
projection image by searching the second projection  
image for the same area as the template by  
performing pattern matching while shifting the  
20 template by an interval;

slice position correcting means for  
correcting the slice position according to the shift  
amount between the first projection image and the  
second projection image; and

25 displaying means for displaying the  
diagnostic image and the comparison image at a  
corrected slice position on a monitor.

The above object of the present invention  
is also achieved by a slice image automatic  
30 alignment apparatus for extracting a comparison  
image corresponding to a diagnostic image, the  
diagnostic image being a slice image which is one of  
first tomographic images, the comparison image being  
a slice image which is one of second tomographic  
35 images which are taken at the time different from  
the time when the first tomographic images are taken,  
body section being a slice plane in the X-Y axial

direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first tomographic images and the second tomographic  
5 images;

resolution aligning means for aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of the tomographic images when the resolutions of the  
10 first tomographic images and the second tomographic images are different;

projection image generation means for generating a first projection image from the first tomographic images and a second projection image  
15 from the second tomographic images;

template generation means for generating a template from the first projection image such that the template includes an area in which a specific object image exists;

20 matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same area as the template by performing pattern matching while shifting the  
25 template by an interval; and

slice position correcting means for correcting the slice position according to the shift amount between the first projection image and the second projection image.

30 According to the above mentioned apparatus, the shift can be detected quickly. By correcting the shift in the comparison images, automatic aligning for slice images can be performed quickly.

The above object of the present invention  
35 is also achieved by a slice image automatic alignment apparatus for extracting a comparison image corresponding to a diagnostic image, the

diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at a time different from the  
5 time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first  
10 tomographic images and the second tomographic images;

resolution aligning means for aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of  
15 the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

reference position recognition means for finding a reference position in the Y axial  
20 direction from each of the first tomographic image and the second tomographic image;

shift correcting means for correcting shift in the Y axial direction on the basis of the reference position;

25 projection image generation means for generating a first projection image of the X axial direction from the first tomographic images and generating a second projection image of the X axial direction from the second tomographic images;

30 template generation means for generating a template from the first projection image such that the template includes an area in which a specific object image exists;

35 matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same area as the template by

performing pattern matching while shifting the template by an interval; and

slice position correcting means for correcting the slice position according to the shift amount between the first projection image and the second projection image.

The above object of the present invention is also achieved by a slice image automatic alignment apparatus for extracting a comparison image corresponding to a diagnostic image, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at a time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first tomographic images and the second tomographic images;

resolution aligning means for aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

projection image generation means for generating a first projection image of the X axial direction from the first tomographic images and generating a second projection image of the X axial direction from the second tomographic images;

reference position recognition means for finding a reference position in the Y axial direction from each of the first projection image and the second projection image;

shift correcting means for correcting

shift in the Y axial direction on the basis of the reference position;

template generation means for generating a template from the first projection image such that  
5 the template includes an area in which a specific object image exists;

matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection  
10 image for the same area as the template by performing pattern matching while shifting the template by an interval; and

slice position correcting means for correcting the slice position according to the shift  
15 amount between the first projection image and the second projection image.

According to the above mentioned apparatuses, the shift can be detected quickly. By correcting the shift in the comparison images,  
20 automatic aligning for slice images can be performed quickly. In addition, since shift correcting is performed by using the bed position or a distinctive part of the body as a reference, search area can be narrowed. Therefore, calculation amount can be  
25 decreased.

In addition, the present invention is a computer readable medium storing program for causing a computer to perform processes according to the method of the present invention.

30 According to the computer readable medium, a program of the present invention can be stored or distributed. In addition, it becomes easy to realize the present invention by using a computer.

#### 35 BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from

the following detailed description when read in conjunction with the accompanying drawings, in which:

5 Figs.1A and 1B are diagrams for explaining X, Y, and Z axes in a chest CT image according to an embodiment of the present invention;

Fig.2A is a diagram for explaining projection directions according to a first embodiment of the present invention;

10 Figs.2B and 2C are diagrams showing examples of a projection image;

Fig.3 is a schematic diagram showing a configuration example of a chest CT image alignment apparatus according to the first embodiment;

15 Fig.4 is a block diagram showing another configuration example of the chest CT image alignment apparatus according to the first embodiment;

20 Fig.5 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image of the same position according to the first embodiment;

25 Fig.6 is a flowchart showing generation process of the projection image of the diagnostic images according to the first embodiment;

Fig.7 is a flowchart showing generation process of the projection image of the comparison images according to the first embodiment;

30 Fig.8 is a diagram for explaining template pattern matching method according to the first embodiment;

Fig.9A shows the direction of projection according to a second embodiment of the present invention;

35 Fig.9B is a projection image in the X axial direction according to the second embodiment;

Fig.10 is a schematic diagram showing a

configuration example of a chest CT image alignment apparatus according to the second embodiment;

Fig.11 is a block diagram showing another configuration example of the chest CT image alignment apparatus according to the second embodiment;

Fig.12 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image of the same position according to the second embodiment;

Fig.13A is a diagram for explaining a reference point for correcting shift in the Y axial direction according to the second embodiment;

Fig.13B is a diagram for explaining a reference point for correcting shift in the Y axial direction according to a third embodiment;

Fig.14 is a diagram for explaining template pattern matching method according to the second and third embodiments;

Fig.15 is a block diagram showing a configuration example of the chest CT image alignment apparatus according to the third embodiment;

Fig.16 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image of the same position according to the third embodiment;

Fig.17 is a block diagram showing a hardware configuration of a computer;

Fig.18 is a diagram for explaining signal assignment;

Fig.19 shows relations between a slider position, a channel and a value;

Fig.20 is a diagram for explaining a method for assigning channels, control numbers and the combinations.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following embodiments of the present invention will be described with reference to figures.

5           In the following embodiments, concerning chest X ray CT images for lung cancer screening, present images are compared with previous images. (first embodiment)

10           The first embodiment of the present invention will be described.

          Figs.1A and 1B are diagrams for explaining X, Y, and Z axes in the chest CT image. Assume that the X-Y axial direction forms a slice plane of a tomographic of body such as chest or the like as shown in Fig.1B, and that the Z axial direction is a moving direction of a patient bed as shown in Fig.1A. The chest X ray CT images for lung cancer screening are taken by a helical scan CT shown in Fig.1A and information of slice thickness in the Z axial direction is included in a slice image of chest tomographic of X-Y axial direction. The number of images to be taken is from 25 to 30 for one person.

          Figs.2B and 2C are diagrams showing examples of a projection image. Fig.2A shows the direction of projection. Fig.2B is a projection image in which all CT values, which are gray levels, are added in the X axial direction as shown in Fig.2A. Fig.2C is a projection image in which all CT values, which are gray levels, are added in the Y axial direction shown in Fig.2A. In this embodiment, the projection image of the Y axial direction as an example will be used.

          Fig.3 is a schematic diagram showing a configuration example of a chest CT image alignment apparatus according to the embodiment.

          A reference number 1 shows a file storing chest tomographic images (diagnostic images) taken

this year and a reference number 2 shows a file storing chest tomographic images (diagnostic images) taken last year. A reference number 3 shows a projection image generated by the file 1 and a  
5 reference number 4 shows a projection image generated by the file 2. In the sequence of CT images stored in the files 1, 2, position shift between past images and present images is occurred due to differences of subject positions or by  
10 deformation of lung due to breathing. A reference number 5 shows a computer system for automatically aligning position of slice images of the file 1 with position of slice images of the file 2 and displaying slice images at a position obtained by  
15 the alignment.

Fig.4 is a block diagram showing another configuration example of the chest CT image alignment apparatus according to the embodiment.

The chest CT image alignment apparatus  
20 includes a terminal apparatus 11 to which a tomographic image reading apparatus 12, a mouse 13, a keyboard 14, and a monitor 15 are connected. The terminal apparatus 11 includes an apparatus control part 111 and a slice image automatic alignment  
25 function part 112 for tomographic images. The slice image automatic alignment function part 112 for tomographic images includes a slice image automatic alignment function and control part 112-1 for tomographic images, a diagnostic image sequence file  
30 112-10, a comparison image sequence file 112-11 and a correction image sequence file 112-12 of comparison images. An operating input part 112-2, a tomographic image external input part 112-3, a resolution matching processing part 112-4, a  
35 projection image generation processing part 112-5, a template generation processing part 112-6, a matching processing part 112-7, a slice position

correction processing part 112-8, and a display processing part 112-9 are connected to the slice image automatic alignment function and control part 112-1 for tomographic images. The operating input  
5 part 112-2 performs data input by connecting the mouse 13 and the keyboard 14. The tomographic image external input part 112-3 inputs tomographic images from the tomographic image reading apparatus 12. The display processing part 112-9 displays  
10 diagnostic images and comparison images to the monitor 15.

Fig. 5  
The tomographic image external input part 112-3 writes data to the diagnostic image sequence file 112-10. The resolution matching processing  
15 part 112-4 reads data from the diagnostic image sequence file 112-10 and the comparison image sequence file 112-10. In addition, the resolution matching processing part 112-4 writes to the correction image sequence file 112-12 of comparison  
20 images. The projection image generation processing part 112-5 and the display processing part 112-9 read data from the diagnostic image sequence file 112-10 and the correction image sequence file 112-12 of comparison images.

25 A MIDI device 16 such as a pedal, a dial, and a slider is connected to the operating input part 112-2. Using the MIDI device, it is possible to adjust the position of the Z axial direction of tomographic images displayed on the monitor minutely.  
30 The detailed description of the MIDI device will be given later.

Fig.5 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image at the  
35 same position in order to support image comparison by software in the computer shown in Fig.3 or by each processing part of the image alignment

apparatus shown in Fig.4. In the flowchart, parenthesized processing parts, which are included in the image alignment apparatus in Fig.4, corresponding to the following procedure are shown.

5 The flowchart will be described.

In Fig.5, diagnostic image sequence  $f_z(x, y)$  which is a slice image sequence and comparison image sequence  $g_z(x, y)$  which is also a slice image sequence are input in step 1 (tomographic image external input part 112-3).

In step 2, when resolution of the diagnostic images and resolution of the comparison images are different, resolution matching processing is performed for correcting the comparison images such that the resolution of the comparison images agree with that of the diagnostic images by scaling using three-dimensional interoperation or leaner interpolation (resolution matching processing part 112-4).

20 Next, in step 3, projection images for each images of the diagnostic images and the comparison images are generated (projection image generation processing part 112-5).

Fig.6 is a flowchart showing generation process of the projection image of the diagnostic images.

First, three-dimensional diagnostic images (slice image sequence) which comprise pixel density on the XY plane are added in the Y axial direction such that a two dimensional image which comprises pixel density on the X axis is formed. That is, assuming that the size of the slice image in the Y axial direction is YSIZE, the projection image  $d_1(x, z)$  of the diagnostic images in the Z axial direction is calculated by adding values in the Y axial direction as shown in the following equation (1).

$$d_1(x, z) = (\sum_{y=0}^{YSIZE} f_z(x, y)) / YSIZE \dots (1)$$

Then, an almost seamless image sequence is generated from the discrete projected diagnostic image sequence by using a leaner interpolation method or a three-dimensional interpolation method such that the projection image of the diagnostic images comprising pixel density is generated on the XZ plane. According to this processing, when computer processing is used, a completely continuous function can not be dealt with. Therefore, almost seamless images which are spaced at 1 mm intervals are generated from images spaced at Z axial direction (body axis direction) intervals of cm order. That is, when generating the projection image from the added image sequence, the Z axial direction is interpolated by the leaner interpolation method or the three-dimensional interpolation method. Concerning the interpolation methods, the leaner interpolation method is better from the point of view of processing speed. When performing interpolation by the three-dimensional interpolation method, the following equations (2) and (3) are used.

$$d(x_0, z_0) \equiv \sum_k \sum_l d(x_k, z_l) c(x_k - x_0) c(z_l - z_0) \dots (2)$$

$$C(w) = \begin{cases} 1 - 2|w|^2 + |w|^3 & 0 \leq |w| < 1 \\ 4 - 8|w| + 5|w|^2 - |w|^3 & 1 \leq |w| < 2 \\ 0 & 2 \leq |w| \end{cases} \dots (3)$$

Next, in step 4 in Fig.5, a projection image of the comparison images is generated in the same way mentioned above. Fig.7 shows the generation process.

First, three-dimensional correction images (comparison images on which resolution matching processing is performed) which comprises pixel density on the XY plane are added in the Y axial direction such that a two dimensional correction

image which comprises pixel density on the X axis is generated. That is, assuming that the size of the slice image in the Y axial direction is YSIZE, the projection image sequence  $d_1(x, z)$  in the Z axial direction is generated by adding values in the Y axial direction as shown in the following equation (4).

$$d_2(x, z) = (\sum_{y=0}^{YSIZE} g_z(x, y)) / YSIZE \dots (4)$$

Then, an almost seamless image sequence is generated from the discrete comparison image sequence on the basis of the leaner interpolation method or the three-dimensional interpolation method such that the projection image comprising pixel density on the XZ plane is generated. Since computer processing is used, a completely continuous function can not be dealt with. Therefore, almost seamless images spaced at 1 mm intervals are generated from images spaced at Z axial direction intervals of cm order. That is, when generating the projection image from the added image sequence of the comparison images, interoperation is performed in the Z axial direction by the leaner interpolation method or the three-dimensional interpolation method since the resolution of the X axial direction and the resolution of the Z axial direction are different. Concerning the interpolation methods, the leaner interpolation method is better from the point of view of processing speed. When performing interpolation by the three-dimensional interpolation method, the above-mentioned equations (2) and (3) are used.

The interpolation methods in the Z axial direction are not limited to the leaner interpolation method and the three-dimensional interpolation method. A most neighborhood method can also be used. In addition, the order in which the projection process is performed on the

diagnostics images or the comparison images can be reversed. Interpolation for both of the images is performed after a CT value adding process for both of the images is performed. There is another method  
5 for generating the projection images in which slice images at intervals of cm is are interpolated so as to generate slice images at intervals of mm, and then, the adding process is performed on the generated slice images. However, by using the  
10 method of the above-mentioned embodiment in which the adding process is performed before interpolation, processing can be performed faster.

Next, in step 5 in the flowchart, a template for searching the projection image of the  
15 comparison images by the projection image of the diagnostics images (template generation processing part 112-6). Fig.8 is a diagram for explaining template pattern matching when using the projection image in the Y axial direction.

20 In the example shown in Fig.8, a rectangular template is generated in the projection image around the area of aortic arch which is in the upper part of lung. That is, the template covers the area of 25%~50% from the top end of the image  
25 in the Z axial direction and 10%~90% from the left end of the image in the X axial direction which covers width of lung in the image. Generally, in the projection image of the diagnostic images, the rectangular template is generated as an area which  
30 is A%~B% ( $A, B \in [0, 100]$ ) from the top end of the object in the Z axial direction and U%~V% ( $U, V \in [0, 100]$ ) from the left end of the object in the X axial direction.

In the case that the object of the  
35 diagnostic images is lung, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as

mentioned above, the after-mentioned pattern matching can be performed effectively. Generally, it is desirable that the area of the template is determined such that texture is relatively plainly visible and amount of change of the image due to breathing or the like is small.

Next, pattern matching is performed in step 6. That is, in order to search for an area in the comparison projection image which is the same as the template, pattern matching is performed while shifting the center of the template by several mm from  $(50-25)/2=12.5\%$  to  $100-12.5=87.5\%$  in the Z axial direction and from  $(90-10)/2=40\%$  to  $100-40=60\%$  in the X axial direction. Generally, pattern matching is performed while shifting the center of the template from  $(B-A)/2\%$  to  $100-(B-A)/2\%$  in the Z axial direction and from  $(V-U)/2\%$  to  $100-(V-U)/2\%$  in the X axial direction (matching processing part 112-7).

Finally, in step 7, when the same area as the template is found in the comparison projection image, the shift amount of the comparison projection image in the Z axial direction is measured and the slice position of the comparison image sequence is corrected by the shift amount (slice position correction processing part 112-8). Then, in step 8, the diagnostic image and the comparison image in the slice position which has been corrected are displayed on a display of the image comparison system in Fig.3 or the monitor (monitor 15) of the image alignment apparatus in Fig.4 (display processing part 112-9).

After displaying the images on the display, precise position adjustment is available by using the MIDI device such as the pedal, the dial or the slider. That is, each of the positions of the diagnostic images and the comparison images can be

adjusted in the Z axial direction. In addition, after the position is adjusted, both of the slice images can be displayed while synchronizing them. Accordingly, by using a MIDI device for terminal operation in the image comparison, the operation becomes effective.

In the above-mentioned embodiment, the direction for projection is not limited to the Y axial direction. The X axial direction and any other directions can be used. In addition, the method for adjusting resolution is not limited to scaling the comparison images. There's nothing wrong with using methods such as scaling the diagnostic images or scaling both of the images.

(second embodiment)

Next, the second embodiment of the present invention will be described.

In the following embodiment, concerning chest X ray CT images for lung cancer screening, it is assumed that present images are compared with previous images.

The definitions of the X, Y and Z axes are the same as those shown in Figs.1A and 1B. That is, the X-Y axial direction forms a slice plane of a tomographic of a body such as chest or the like as shown in Fig.1B, and the Z axial direction is a moving direction of a patient bed as shown in Fig.1A. The chest X ray CT images for lung cancer screening are taken by a helical scan CT shown in Fig.1A and information of slice thickness in the Z axial direction is included in a slice image of chest tomographic of X-Y axial directions. The number of images to be taken is from 25 to 30 for one person.

Figs.9A and 9B are diagrams showing examples of projection. Fig.9A shows the direction of projection. Fig.9B is a projection image in

which all CT values, which are density value in the image, are added in the X axial direction shown in Fig.9A.

Fig.10 is a schematic diagram showing a configuration example of a chest CT image alignment apparatus according to the embodiment.

A reference number 21 shows a file storing chest tomographic images (diagnostic images) taken this year and a reference number 22 shows a file storing chest tomographic images (comparison images) taken past year. A reference number 23 shows an X axis direction projection image generated by the file 21 and a reference number 24 shows an X axis direction projection image generated by the file 22. In the sequence of CT images stored in the files 21, 22, position shift between slices has occurred due to a difference of subject positions or by deformation of lung due to breathing. A reference number 25 shows a computer system for automatically aligning positions of slice images of the file 21 and position of slice images of the file 22 and displaying slice images at an aligned position.

Fig.11 is a block diagram showing another configuration example of the chest CT image alignment apparatus according to the embodiment.

The chest CT image alignment apparatus includes a terminal apparatus 31 to which a tomographic image reading apparatus 32, a mouse 33, a keyboard 34, and a monitor 35 are connected. The terminal apparatus 31 includes an apparatus control part 311 and a slice image automatic alignment function part 312 for three-dimension tomographic images. The slice image automatic alignment function part 312 for three-dimension tomographic images includes a slice image automatic alignment function and a control part 312-1 for three-dimension tomographic images, a diagnostic image

sequence file 312-12, a comparison image sequence  
file 312-13 and a correction image sequence file  
312-14 of comparison images. An operating input  
part 312-2, a tomographic image external input part  
5 312-3, a resolution matching processing part 312-4,  
a bed position extracting part 312-5, a shift  
correction processing part 312-6, a projection image  
generation processing part 312-7, a template  
generation processing part 312-8, a matching  
10 processing part 312-9, a slice position correction  
processing part 312-10, and a display processing  
part 312-11 are connected to the slice image  
automatic alignment function and control part 312-1  
for three-dimension tomographic images. The  
15 operating input part 312-2 performs operating input  
by connecting the mouse 33 and the keyboard 34. The  
tomographic image external input part 312-3 inputs  
tomographic images from the tomographic image  
reading apparatus 32. The display processing part  
20 312-11 displays diagnostic images and comparison  
images to the monitor 35.

*Fig. 7* The tomographic image external input part  
312-3 writes data to the diagnostic image sequence  
file 312-12. The resolution matching processing  
25 part 312-4 reads data from the diagnostic image  
sequence file 312-12 and the comparison image  
sequence file 312-14. In addition, the resolution  
matching processing part 312-4 writes in the  
correction image sequence file 312-14 of comparison  
30 images. The shift correction processing part 312-6  
corrects shift between the diagnostic image and the  
comparison image based on the bed position. The  
projection image generation processing part 312-7  
and the display processing part 312-11 read data  
35 from the diagnostic image sequence file 312-12 and  
the correction image sequence file 312-14 of  
comparison images.

A MIDI device 36 such as a pedal, a dial, and a slider which is mentioned before is connected to the operating input part 312-2.

Fig.12 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image of the same position by software in the computer shown in Fig.10 or by processing parts of the image alignment apparatus shown in Fig.11 in order to support image comparison. In the flowchart, parenthesized processing parts, which are included in the image alignment apparatus in Fig.11, corresponding to the following procedure are shown. The flowchart will be described.

In Fig.12, diagnostic image sequence  $f_z(x, y)$  and comparison image sequence  $g_z(x, y)$  are input in step 11 and step 12 (tomographic image external input part 312-3).

In step 13, when resolution of the diagnostic images and resolution of the comparison images are different, resolution matching processing is performed for correcting the comparison images such that the resolution of the comparison images agree with that of the diagnostic images by scaling using three-dimension interoperation or leaner interpolation (resolution matching processing part 312-4).

In step 14 and 15, a bed area is extracted from each of the first diagnostic image and the first comparison image (bed position extracting part 312-5). Then, in step 16, Y axis direction shift between the diagnostic image and the comparison images is corrected on the basis of the extracted bed position in which the Y axis direction is perpendicular to the bed position (shift correction processing part 316-6). The bed area is shown in Fig.13A.

In step 17 and step 18, an X axis direction projection image is generated in which the X axis is defined as a direction perpendicular to the corrected Y axis direction (projection image generation processing part 312-7). Projection images are calculated as shown in formulas (5) and (6) in which XSIZE is the size of the slice image in the X axis direction,  $d_1(y, z)$  is the X axis direction projection image of the diagnostic images and  $d_2(y, z)$  is the X axis direction projection image of the comparison images.

$$d_1(y, z) = (\sum_{x=0}^{XSIZE} f_z(x, y)) / XSIZE \dots (5)$$

$$d_2(y, z) = (\sum_{x=0}^{XSIZE} g_z(x, y)) / XSIZE \dots (6)$$

Since the resolution of the images for screening in the Y axial direction is different from that in the Z axial direction, the projection images are interpolated by the leaner interoperation method or the three-dimensional interpolation method. A most neighborhood method can also be used for interoperation.

Next, in step 19, as shown in Fig.14, a rectangular template is generated in the projection image around the area of the aortic arch which is in the upper part of lung. That is, the template covers the area of 25%~50% from the top end of the image in the Z axial direction and 10%~90% from the left end of the image in the Y axial direction which covers width of lung in the image. In step 20, in order to search for the same area in the comparison projection image as the template, pattern matching is performed while shifting the center of the template by several mm in the Z axial direction and in the Y axial direction. When the same area as the template is found in the comparison projection image, in step 21, the shift amount of the comparison projection image in the Z axial direction

is measured and the slice position of the comparison image sequence is corrected by the shift amount. In step 22, the diagnostic image and the comparison image in the slice position which has been corrected are displayed on a display of the image alignment system in Fig.10 or the monitor (monitor 35) of the image alignment apparatus in Fig.11. After displaying the images on the display, precise position adjustment is available by using the MIDI device such as the pedal, the dial or the slider.

In the second embodiment, similar to the first embodiment, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as mentioned above, the pattern matching can be performed effectively. (third embodiment)

As shown in Fig.13B, it is also possible to extract the bed area after generating the projection image. In the following, an embodiment in which the bed area is extracted after generating the projection image will be described as the third embodiment.

Fig.15 is a block diagram showing an configuration example of the chest CT image alignment apparatus according to the embodiment. The apparatus can be configured as a computer system in the same way as the second embodiment shown in Fig.10.

The chest CT image alignment apparatus includes a terminal apparatus 41 to which a tomographic image reading apparatus 42, a mouse 43, a keyboard 44, and a monitor 45 are connected. The terminal apparatus 41 includes an apparatus control part 411 and a slice image automatic alignment function part 412 for tomographic images. The slice image automatic alignment function part 412 for tomographic images includes a slice image automatic

alignment function and control part 412-1 for tomographic images, a diagnostic image sequence file 412-12, a comparison image sequence file 412-13 and correction image sequence file 412-14 of comparison  
5 images. An operating input part 412-2, a tomographic image external input part 412-3, a resolution matching processing part 412-4, a projection image generation processing part 412-5, a bed position extracting part 412-6, a shift  
10 correction processing part 412-7, a template generation processing part 412-8, a matching processing part 412-9, a slice position correction processing part 412-10, and a display processing part 412-11 are connected to the slice image  
15 automatic alignment function and control part 412-1 for tomographic images. The operating input part 412-2 performs operating input by connecting the mouse 43 and the keyboard 44. The tomographic image external input part 412-3 inputs tomographic images  
20 from the tomographic image reading apparatus 42. The display processing part 412-11 displays diagnostic images and comparison images to the monitor 35.

The tomographic image external input part  
25 412-3 writes data to the diagnostic image sequence file 412-12. The resolution matching processing part 412-4 reads data from the diagnostic image sequence file 412-12 and the comparison image sequence file 412-10. In addition, the resolution  
30 matching processing part 412-4 writes in the correction image sequence file 412-12 of comparison images. The shift correction processing part 412-7 corrects shift between the diagnostic image and the comparison image based on the bed position. The  
35 projection image generation processing part 412-5 and the display processing part 412-11 read data from the diagnostic image sequence file 412-12 and

the correction image sequence file 412-14 of comparison images.

5 A MIDI device 46 such as a pedal, a dial, or a slider which is mentioned before is connected to the operating input part 412-2.

10 Fig.16 is a flowchart showing a procedure for measuring position shift and displaying the diagnostic image and the comparison image of the same position by software in the computer system or by processing parts of the image alignment apparatus shown in Fig.15 in order to support image comparison. In the flowchart, parenthesized processing parts, which are included in the image alignment apparatus in Fig.15, corresponding to the following procedure are shown. The flowchart will be described.

15 In Fig.16, diagnostic image sequence  $f_z(x, y)$  and comparison image sequence  $g_z(x, y)$  are input in step 31 and step 32 (tomographic image external input part 412-3).

20 In step 33, when resolution of the diagnostic images and resolution of the comparison images are different, resolution matching processing is performed for correcting the comparison images such that the resolution of the comparison images agree with that of the diagnostic images by scaling using three-dimensional interoperation or leaner interpolation (resolution matching processing part 412-4).

30 In step 34 and step 35, X axis direction projection images are generated (projection image generation processing part 412-7). Projection images are calculated as shown in formulas (7) and (8) in which XSIZE is the size of the slice image in the X axis direction,  $d_1(y, z)$  is the X axis direction projection image of the diagnostic images and  $d_2(y, z)$  is the X axis direction projection image of the comparison images.

$$d_1(y, z) = (\sum_{x=0}^{XSIZE} f_z(x, y)) / XSIZE \dots (7)$$

$$d_2(y, z) = (\sum_{x=0}^{XSIZE} g_z(x, y)) / XSIZE \dots (8)$$

Since the resolution of the images for screening in the Y axis direction is different from that in the Z axis direction, the projection images are interpolated by the leaner interoperation method or the three-dimensional interpolation method. A most neighborhood method can also be used for the interoperation method.

10 In step 36 and 37, a bed area is extracted from each of the diagnostic projection image and the comparison projection image (bed position extracting part 412-5). Then, in step 38, Y axis direction shift between the diagnostic image and the  
15 comparison images is corrected on the basis of the extracted bed position in which the Y axis direction is defined as a direction perpendicular to the bed position (shift correction processing part 412-6). The bed area is shown in Fig.13B.

20 Next, in step 39, as shown in Fig.14, a rectangular template is generated in the projection image around the area of aortic arch which is in the upper part of lung. That is, the template covers the area of 25%~50% from the top end of the image  
25 in the Z axial direction and 10%~90% from the left end of the image in the Y axial direction which covers width of lung in the image. In step 40, in order to search for the same area in the comparison projection image as the template, pattern matching  
30 is performed while shifting the center of the template by several mm in the Z axial direction and in the Y axial direction. When the same area as the template is found in the comparison projection image, in step 41, the shift amount of the comparison  
35 projection image in the Z axial direction is measured and the slice position of the comparison

image sequence is corrected by the shift amount. In step 42, the diagnostic image and the comparison image in the slice position which has been corrected are displayed on a display of the image alignment system in Fig.10 or the monitor (monitor 45) of the image alignment apparatus in Fig.15. After displaying the images on the display, precise position adjustment is available by using the MIDI such as the pedal, the dial or the slider.

10 In the third embodiment, similar to the first embodiment, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as mentioned above, the pattern matching can be performed effectively.

15 In the second and third embodiments, other distinctive areas such as a backbone area or a body part contacting the bed area can be used as the reference for correcting Y axis direction shift between the diagnostic image and the comparison image.

20 In the first, second and third embodiments, when generating the projection image of the diagnostic images or the comparison images, better matching result for the part of bone can be obtained by generating tomographic images in which weight is assigned to bone parts and perform matching by using the images. Specifically, in the above method, image representation density is not set by using density gradation of the actual CT image which is from 0 level to the maximum level gray-scale. Instead, a window level (central density value) and a window width (density width from the central density value) is set by using a mediastinum condition in which bone is highly visible.

25 30 35 Similarly, by setting the representation density as the window level and the window width by using lung area condition in which lung texture is highly

visible, better matching result for the part of lung texture can be obtained by generating tomographic images in which weight is assigned to the lung texture. The MIDI device can be used for setting  
5 the window level and the window width.

In the first, second and third embodiments, the method for adjusting resolution is not limited to scaling the comparison images. There's nothing wrong with using methods such as scaling the  
10 diagnostic images and scaling both of the images.

In the first, second and third embodiments, the chest X ray CT image is described as an example. However, the present invention is applicable to tomographic images of other parts and applicable to  
15 tomographic images other than the CT images.

Further, in the first, second and third embodiments, better matching result for a specific part and speedy processing can be realized by generating the projection image in which only an  
20 area including the specific part is added in a direction and by performing matching by using the projection image, the specific part including a distinctive part.

Further, in the first, second and third  
25 embodiments, when measuring the shift amount between the projection image of the diagnostic images and the projection image of the comparison images, a plurality of templates can be generated from the projection image of the diagnostic images and  
30 template matching can be performed by using the templates on the projection image of the comparison images such that the shift amount is measured from a plurality of reference points. Accordingly, shift correction of the slice position becomes more  
35 accurate and the better matching result can be obtained. Especially, when comparing the lower part of lung, shift due to breathing can be corrected.

Further, in the embodiments, the procedures shown in Figs.5, 6, 7, 12 and 16 can be realized by a computer as mentioned above. The program for performing the procedure can be stored  
5 in a computer-readable medium such as a FD(floppy disk), an MO, a ROM, a memory card, a CD, a DVD, a removable disk or the like. In addition, providing or distributing the medium is possible.

Fig.17 is a block diagram showing a  
10 hardware configuration of such a computer. As shown in Fig.17, the computer system includes a CPU 500 by which a process of a program is executed, a memory 501 for temporarily storing data and a program, a hard disk 502 for storing data and a program to be  
15 loaded into the memory 501, a display 503 for displaying data, a keyboard 504 for inputting data or commands, a CD-ROM drive 505 and a communication processing unit 506 which enables the computer system to communicate with other computers via a  
20 network. The program is installed in the hard disk 502 via the CD-ROM drive 505 then loaded into memory 501 and executed by the CPU 500. According to the computer, the image alignment of the present invention can be performed.

25 As mentioned above, according to the image alignment apparatus of the present invention, slice images of the same body position can be obtained automatically at high speed from two groups of the chest tomographic images of the same person such  
30 that the slice images can be presented to a doctor in a short time. In addition, some work for comparing the images beforehand and excessive computer memory area become unnecessary. Further, by using the template which is 25%~50% from the  
35 top end of the projection images in the Z axial direction, pattern matching can be performed effectively such that position alignment is

performed quickly.

In the following, a description is provided of the MIDI device which is connected to the operation input part of the image alignment apparatus for control purposes.

Generally, MIDI (Musical Instrument Digital Interface) is a communication control standard for electronic musical instruments which is supported by many personal computers. When a control device such as a dial, a slider or a pedal is necessary for control of a computer, a control device supporting MIDI can be connected relatively easily and the control device can be easily changed and easily increased.

Generally, resolution of 128 stages of 0-127 are defined for describing continuous amount change in MIDI signals. Therefore, it does not support control which is finer than the 128 stages. Thus, when control which is finer than the 128 stages is necessary in MIDI, a system exclusive message (exclusive information for the system) is used. In this case, although the information is in conformity with the MIDI standard, there is no compatibility. As a result, it becomes difficult to change to another control device which is commercially available.

On the other hand, the MIDI device used for the image alignment apparatus can receive and send signals of higher resolution than 128 stages while keeping compatibility with commercially available MIDI devices. In the following, the method for receiving and sending the signals of higher resolution will be described. Here, a MIDI slider is taken as an example and the case in which 256 stage resolution is necessary is taken as an example.

Generally, the control signal of MIDI

device has resolution of 128 stages of 0-127.  
Therefore, if it is used as it is, higher resolution  
than 128 stages can not be realized. For this  
reason, a 256 stage resolution MIDI slider is  
5 designed in which two MIDI channels are used and  
data is output by assigning alternately to the  
channels as shown in Figs.18 and 19.

A MIDI control change signal includes a  
first byte (MIDI channel : identifying each  
10 instrument), a second byte (control No. : specifying  
a type of control medium) and a third byte (control  
value : specifying concrete control value).

It is desirable that channels and control  
numbers used for realizing high resolution are those  
15 which are not mainly used in a normal controller.  
However, to simplify the description, the original  
MIDI signal uses a channel 1 and a control number A,  
and MIDI channel 2 and the same control number A are  
used for realizing high resolution.

20 An application in the MIDI signal  
receiving side receives position values of the  
slider, each of which position value is one of  
values obtained by dividing slider change width into  
128. In addition, when a value comes from the  
25 channel 2, the application is set such that it  
interprets the value as  $1/256$  higher than a value  
of the channel 1.

In Fig.19, "slider position" corresponds  
to a value in 256 stages (the range is from 124 to  
30 143 for the sake of convenience), "ch" is the  
channel and "value" is the value of 128 stages  
output from a slider. When using one channel, the  
values of 128 stages of the right section are  
converted into the value of 256 stages ( $62/128 \rightarrow 124$   
35  $/256$ ). When two channels,  $1/256$  is added to the  
values converted to 256 stages ( $62/128 \rightarrow 124/256 + 1$   
 $/256 = 125/256$ ) .

As a result, the receiving application can recognize the position of the slider at 256 stage resolution when using the high resolution MIDI slider. In addition, when a normal MIDI slider is  
5 connected instead of the high resolution slider, the normal MIDI slider can receive the same information without any modification.

The high resolution slider is a slider which can use higher resolution signal than the  
10 conventional slider. Conventionally, one channel and one control number is assigned to a slider and the slider outputs a value from 1 to 128 according to the movement of the slider. On the other hand, necessary channels and control numbers for realizing  
15 high resolution are assigned to the high resolution MIDI slider which outputs signals by synthesizing the channels and control numbers according to the method of the present invention. In the present invention, only the value of the slider and the  
20 method for assigning the MIDI signal are defined. Hardware and the configuration for realizing the method are not defined.

By assigning control number instead of the channel, the same effect can be obtained. In  
25 practical use, an unassigned channel or a unassigned control number should be selected.

In this embodiment, signals are assigned according to the order of MIDI channels to be multiplexed. In addition, the order can be reverse  
30 or random or the like as long as both the receiving side and the sending side have been correlated.

In this embodiment, high resolution signals are divided into equal parts for grouping. However, the signals are not necessarily divided  
35 uniformly. That is, when only a part needs high resolution, only the part may be divided into smaller parts such that the parts are allocated to a

plurality of channels, control numbers or the combinations.

In addition, it is not necessary to assign the channels, control numbers or the combinations to  
5 fixed specific change areas. Instead, they may be overlapped partially as shown in Fig.20. In this example, six control changes for six MIDI channels are used. In the area A, the resolution is five times larger. In the area B, the resolution is the  
10 same as normal state. This method is applicable when precise control is necessary in only a portion of the change area.

As mentioned above, the MIDI signal constructing method includes the steps of: providing  
15 n different MIDI channels or control numbers or combinations of them for a signal x which has  $128 \times n$  stages in which n is a positive integer; assuming the MIDI channels or the control numbers or the combinations as  $p=1, 2, \dots, n$ ; dividing the signal x  
20 into 128 parts  $W(1)(1; 0 \leq 1 \leq 127)$  in ascending order and assigning p which is equal to  $r+1$  ( $r; 0 \leq r < n$ ) to the signal x which is equal to  $1 \times n + r$ ; constructing and sending a MIDI control change message in which a control value is 1 by using a MIDI channel or  
25 control number corresponding to p.

By using the MIDI signal constructing method, when a specific MIDI controller which outputs signals according to the present invention is used, signals according to the resolution can be  
30 transmitted and received. When a conventional controller is used, the same control as the specific controller can be performed as a whole. Therefore, by using the MIDI device for the image alignment apparatus of the present invention, precise control  
35 can be performed.

The present invention is not limited to the specifically disclosed embodiments, and

variations and modifications may be made without departing from the scope of the invention.

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